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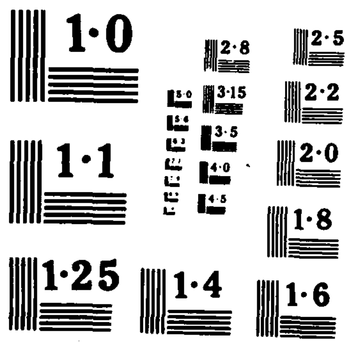
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# FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

THE SECRET OF GUIDED MISSILE RE-ENTRY

by

Chen Jingzhong, An Sehua

FOREIGN TECHNOLOGY DIVISION





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By: Chen Jingzhong, An Sehua

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THE SECRET OF GUIDED MISSILE RE-ENTRY

Chen Jingzhong, An Sehua

Modern intercontinental guided missiles fly ten thousand miles majestically across the great sky. From launch to hitting the target their flight generally consists of three flight stages: propulsion flight, free flight and re-entry flight into the atmosphere. So-called re-entry means returning to the earth's dense atmosphere after the guided missile completes the free flight stage in near vacuum. The success of guided missile re-entry writes a shining page in modern aerospace history!

Starting with Meteors

The meteor is a re-entry phenomenon with which we are familiar. The phenomenon is formed when a meteor body among the stars, under the effects of the earth's gravitational field, flies at high speed into the earth's dense atmosphere and, due to friction with air, emits a great amount of heat and light. During

the process of re-entry, the major portion of the meteor body is burned off. Only a small portion survives and hits the earth's surface as a meteorite. A meteor burns during its re-entry; then, what is the destiny of the warhead of an intercontinental guided missile during its high speed re-entry? Will it be destroyed like the meteor? This is indeed a big problem in the development of guided missiles. In the history of guided missile development, sad scenes of self-destruction during an intercontinental guided missile re-entry were not uncommon. When the United States was developing the "Titan" intercontinental guided missiles during the mid-50's, due to lack of sufficient awareness about the harsh environment of re-entry, the first few re-entry flight tests all failed; in 1965, the United States began research on the "MX-12" model multiple warheads used in "Minuteman III" guided missiles, and many a warhead was burned to ashes in the hostile environment of re-entry flight.

Faced with this cruel reality, no wonder it reminded people of the prediction by modern aerodynamics expert Von Karman: "Re-entry is probably one of the most difficult problems people can imagine. It presents keen challenges to the smartest researchers in the fields of modern aeronautical physics."

"Indestructible Steel" Created out of "Blazing Flame"

As intercontinental guided missiles return to the earth's atmosphere at extremely high speed (about 7 km/sec), the ambient temperature surrounding the guided missile warhead can reach

7,000° C to 11,000° C due to friction with air, which is equivalent to the surface temperature of the sun. Under such "hot flame blazing fire", the warhead could not survive if it were not for its special design. In order to prevent the warhead from burning to destruction in the re-entry environment, modern warheads of the latest model of intercontinental guided missiles, in addition to selecting a suitable blunt-head and cone-shaped profile, mainly adopt extremely stringent high-temperature erosive combustion-resistant material to make the heat resistant tip of the guided missile warhead. As early as the late 60's, the United States Air Force recognized the need to develop and manufacture composite material of carbon fiber and reinforced carbon for guided missile warhead tips. In 1974, the United States Air Force carried out a warhead tip testing project using funds appropriated for the advanced ballistic re-entry system project, and signed separate research and development contracts with General Electric Company and Alfaco Company. The contracts stipulated that warhead tips for "Minuteman III" intercontinental guided missiles be designed and manufactured by both companies. After repetitive testing and competition, the United States Air Force eventually selected the "carbon-carbon" tips developed by Alfaco Company, and installed these tips on the "MK-12A" warheads of the "Minuteman III" intercontinental guided missiles in 1980. This new model of a re-entry warhead heat resistant tip is composed of tip body, heat shield and tip cap-- three parts joined together. Since it adopted a series of special technical treatments such as weaving, penetrating, seeding, submerging, carbonization, graphitization,

cutting, and homogenization for graphite (or carbon) fiber, it can survive the "blazing flame" in the re-entry environment and be "burned but not destroyed", "pulled yet not collapsed". Recently, the Japanese Cosmic Development Ministry developed a new high-temperature erosive combustion resistant material for the "Daiwa" space shuttle. It was produced by submerging carbon fibers into carbon particles, and it possesses extremely high combustion and compression resistance capability.

A New Problem of "Cuts Iron like Mud"

As the understanding of re-entry phenomenon grew more sophisticated, people discovered from practice a strange re-entry problem: when a guided missile passes through "unclean" space that contains particles (including rain drops, ice crystals, snow flakes, particulates, or other man-made particles), a large amount of material on the guided missile warhead tip is "blown away" or "washed off" in solid form from the head cone due to super high speed collision between the guided missile and these particles. People call this "cuts iron like mud", like large-scale "wash off" of the warhead tip, "weather erosion". Serious "weather erosion" will deform the warhead tip, even to the point of "rub off", and affect the accuracy of the guided missile's point of impact. In order to study "weather erosion" problems, the United States Air Force and Navy have invested a large amount of funds since the early 70's in building corresponding ground simulation facilities and have conducted a series of ground simulation tests. On the

basis of ground simulation tests, analytical computer programs have been written to correlate the high-temperature erosive combustion encountered during guided missile re-entry and particle erosion. The United States Air Force Space and Missile System Organization (SAMSO) also approved an advanced ballistic re-entry system project. During the three years after 1973, methods using satellite measurement results for estimating the amount of the guided missile's weather erosion during re-entry have been developed, and equations relating the amount of weather erosion and satellite parameters have been established. These studies have laid a sound foundation to solving the weather erosion problem. Recently, the United States Air Force and Navy proposed so-called "Weather enhancement" proposals in order to increase guided missile survivability under adverse weather conditions. That is, a dual-tip proposal and a self-adjusting sweat/cool proposal. The dual-tip proposal adopts material (e.g. graphite, carbon-carbon, etc.) which is high-temperature erosive combustion resistant to make the outer layer main tip, and it uses erosion resistant material (e.g. tungsten) to make the inner layer sub-tip. During the warhead's re-entry, high-temperature erosive combustion prevails at high altitudes and this is when the main tip is needed; at lower altitude the cloud particle erosion prevails and this is when the sub-tip is needed. The two materials complement each other to achieve the double goals of heat and erosion protection. According to reports, the American Society of Test Aircraft Research and Manufacturing proposed and successfully produced such a re-entry dual-tip, and the effects were good after flight tests.

Figure 2 is the schematic of the self-adjusting sweat/cool proposal. Coolant and catalyst are stored in the tip body. Under the special effects of negative acceleration during the re-entry process, the natural convection betweeen the coolant, whose specific weight is larger, and the catalyst, whose specific weight is smaller, becomes more active, thus causing the tip to "sweat" and cool down. The worse the re-entry environment is, the stronger the "sweat" ability is; therefore, it is called: self-adjusting.

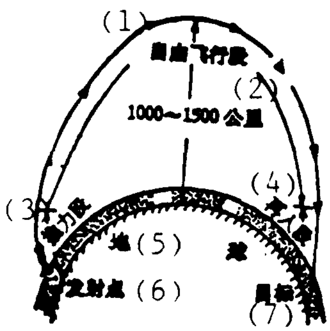


Fig. 1: Typical ballistics of the intercontinental guided missile.
Key: (1) free flight stage; (2) km; (3) propulsion stage; (4) re-entry stage; (5) Earth; (6) launch site; (7) target.

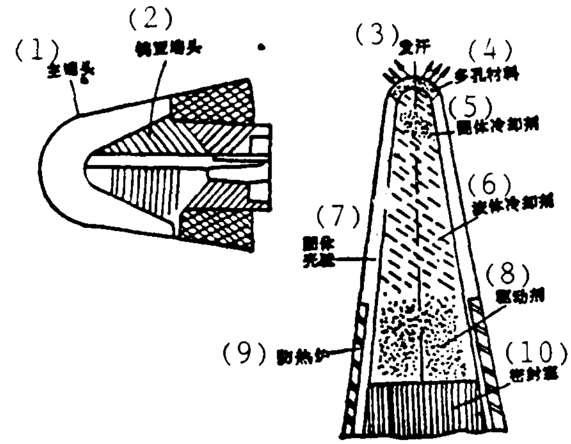


Fig.2: Self-adjusting sweat/cool tip.
Key: (1) main tip;(2) tungsten sub-tip; (3) sweat; (4) porous material; (5) solid coolant; (6) liquid coolant; (7) solid wall shell; (8) catalyst; (9) heat shield; (10) air-tight seal.

Out of Ten Thousand-fold of "Blockade" Comes Good News

The high temperature produced by friction with the air during a guided missile high-speed re-entry can cause the air molecules surrounding the warhead to sufficiently ionize. In addition, part of the heat resistant material of the warhead is sufficiently ionized after being erosively combusted and thereby forming an equa-ion shell layer - commonly known as an equa-ion sheath. The highly electrically conductive equa-ion sheath acts as if it were a metal shield covering the warhead with a thickness reaching a dozen or more centimeters, and becomes a "forbidden zone" difficult for a radio wave to cross. It causes the communication and remote data sensing to discontinue and flight to be out of control. This phenomenon is called re-entry radio signal blackout.

Re-entry remote data sensing is an important basis for developing configuration and predicting accuracy of point of impact of the guided missile. Therefore, the loss of remote data sensing during the re-entry stage is obviously unacceptable. In order to resolve the difficult problem of re-entry remote sensing communication blackout, the United States began extensive efforts in it research in the 60's. The United States Air Force Cambridge Research Laboratory conducted long term simulation and real flight tests on the subject of re-entry communication. It obtained much experimental data information and presented many feasible measures in solving this problem.

Currently, the common solution for re-entry remote sensing communication blackout is the "store-retransmit" technique. The specific procedures are: to temporarily store remote sensing information of the guided missile within the re-entry signal blackout zone in the storage device inside the guided missile, and after the guided missile flies out of the blackout zone but before self-destruction at touchdown, the information is rapidly transmitted to the ground. In 1963, the United States first used the "store-retransmit" technique on the re-entry remote sensing of the "Polaris" $A_3$ guided missile. The simple operating procedures of this technique are as follows: real time remote sensing data of the guided missile's characteristic operational condition are stored into the storage device at a slow rate of 2.14 pictures/second. After the guided missile flies out of the signal blackout zone, the process mechanism orders the storage device to retransmit at a high rate of 27.8 pictures/sec. The ratio of storage to transmission is 1:13, that is, the temporarily stored data of a 13-second blackout only needs 1 second to complete the fast transmission after the guided missile flies out of the blackout zone, and using process control multiple retransmission can be performed until warhead self-destruction at touchdown. The real time data and stored data are transmitted simultaneously at different frequencies, and the purpose is to guarantee that the guided missile, after flying out of the blackout zone, can not only transmit temporarily stored blackout data, but also transmit instant remote sensing information without interruption.
Currently, the latest generation of store-retransmit devices all

adopt microcomputer control and apply large capacity MOS dynamic floating storage.

Recently, the U.S. Dupont Company produced a material - Teflon T-30 (Polytetrafluoroethylene) which virtually eliminates the re-entry electronic sheath. According to reports, after this material is added into the heat protection material of the warhead tip using special technology, the electron concentration in the warhead re-entry sheath can be greatly reduced, thereby virtually eliminating the sheath and restoring the signal transmission back to normal during the re-entry stage. This great discovery opens a rather optimistic future for the smooth transmission of guided missile re-entry remote sensing and the realization of end maneuverability control!

Breaking through the Defense Line to win Total Victory

In addition to creating the aforementioned re-entry problems such as high temperature combustion damage and weather erosion and causing communication blackout, tremendous re-entry aerodynamic pressure in the harsh re-entry environment can also cause the warhead to develop violent vibration, rolling, re-entry noise and "bright tail" trail, etc., a series of re-entry difficulties. Violent vibration and rolling can either, on the minor side affect attack accuracy or, on the major side, cause serious asymmetrical local combusion damage, even to the point of warhead destruction; serious noise and "bright tail" trail make it impossible for the

guided missile to evade detection by enemy anti-missile radar, and might possibly be intercepted nd the guided missile destroyed during re-entry. What makes it especially serious is that as the development of offensive weapons like intercontinental guided missiles proceeds, the "shield" used against the intercontinental guided missile - the ABM system - also grows more mature by the day; thus check and countercheck become so entangled to the point that neither one has an advantage. For this, resolution of warhead re-entry maneuverability control so as to penetrate the enemy's interception is a "life and death" key to obtaining final total victory for the re-entry of guided missiles.

In addition to adopting electronic interference, counter defense measures for warhead re-entry primarily entail the implementation of warhead maneuverability control to adapt to harsh re-entry environment, thereby evading enemy interception and hitting the predetermined target unexpectedly. From the mid-50's to the early 60's, both the U.S. and the Soviets adopted simple posture control. From the mid-60's to the early 70's, due to advances in the development of anti-missile technology, warhead counter defense became an important issue, and a multi-warhead was developed for this reason. The earler multi-warhead was not individually targeted. In the mid-70's, the individually targeted multi-warhead started to appear. The multi-warhead is composed of mother-ship and several sub-warheads. The mother ship after burner control system consists of afterburner motor, posture motor,

computer and inertia platform. The method of mother ship controlled delivery of sub-warheads is: when the mother ship flies to a certain preset instant, the posture control system is activated to begin action and the sub-warheads are released sequentially under precision guidance and stability control. Since the mother ship has control capability, it can achieve specific maneuvered attack. After releasing all sub-warheads, the mother ship can return to her original launch orbit and proceed with reentry into the atmosphere, thereby serving as a decoy to confuse the "vision" of the ABM system and covering sub-warhead defense penetraion. MIRV guided missiles are currently the main intercontinental guided missile forces of both the U.S. and the Soviets.

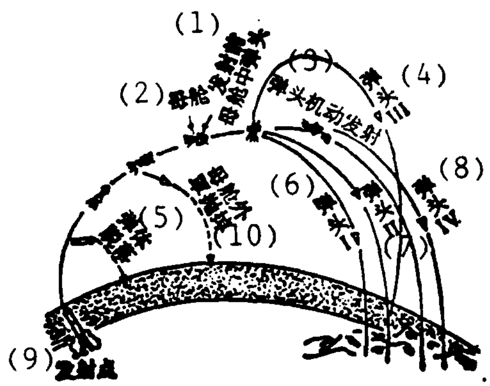


Fig. 3: The delivery of MIRV warheads
Key: (1) warheads in mother ship before launch; (2) mother ship; (3) warhead mechanical launch; (4) warhead III; (5) missile body disengagement; (6) warhead I; (7) warhead II; (8) warhead IV; (9) launch site; (10) mother ship booster drop.

In order to counter the newly developed ABM system, the development of warhead re-entry defense penetration technology continues to advance. At present, not only the mother ship can be controlled, but also amazing achievements in the end guidance control technology for sub-warhead re-entry have been obtained to realize true maneuverability control of warhead re-entry. According to a report in the June 6, 1983 issue of the American "Aviation Weekly" magazine, the United States Air Force and the Pentagon are considering the installation of a so-called "end position setting system" on the "Midget", a small intercontinental guided missile, as a part of reentry maneuverability guidance. This kind of warhead, after its re-entry into the atmosphere, can be maneuvered to fly above the target area in order to eliminate total control errors and evade interception by an enemy ABM system and thus making target accuracy of the "Midget" guided missile the range of which is 9,250 km, to reach 30 meters. Presently, this is the intercontinental guided missile with the highest target accuracy.

The super high speed re-entry of intercontinental guided missiles rapidly develops with scientific technology, and miracles shall continue to appear.

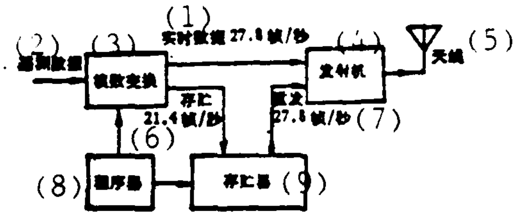


Fig. 4: Schematic of store-retransmit device
Key: (1) Real-time data 27.8 pictures/sec; (2)remote sensing data; (3) mode exchange; (4) transmitter; (5) antenna; (6) storage 21.4 pictures/sec; (7) re-transmission 27.8 pictures/sec; (8) processor; (9) storage device.

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